Manufacturing in 3D: Will 3D Printing Revolutionize Modern Industry?

One afternoon in 2012, Craig Place was browsing the internet and came across an article about printing coat hooks. It featured a machine—the RepRap 3D printer—that you could build and then use to fabricate whatever you wanted. Place was, pardon the pun, hooked. From 4 p.m. until 3 a.m. the next day, the university systems designer sourced printer designs, joined chat rooms, read wikis and connected with a subculture of DIY enthusiasts.

Two weeks later, the printer parts arrived and, with no previous experience in engineering or electronics, he constructed the machine. “It was almost a letdown,” he said. “By the time I’d finished making the printer, there was already an enhancement I could add to it. About 90% of the things I’ve printed so far are upgrades to the RepRap itself.”

Place was not discouraged. By then, he had discovered the nearby Nottingham Hackspace, which opened in 2010. There, like-minded people were engaged in a wide range of maker projects, from building 3D printers and working on laser cutters to designing jewelry, mending bicycles and constructing Arduino electronics components for their personal gadgets.

Based in a red brick Victorian warehouse previously used by the city’s lace makers, Nottingham Hackspace is one of the most successful, self-funded, member-run communities of its kind in the United Kingdom. Founder Dominic Morrow said that anyone can join, elect to pay as much or as little as they want per month, and do whatever they want as long as they obey the safety rules and do not engage in unethical making. Its single floor is roughly divided into sites for working with wood, fabrics, metal, electronics and paint. The membership, which topped 260 last year, is a mixture of hobbyists like Place and those who are prototyping products for business start-ups. Morrow’s own company, Just Add Sharks, which sells and rents laser cutters, originated from his involvement with the space.

“Making is all about passion and enthusiasm,” he said, describing the collective’s DIY attitude as very laissez-faire. There is no top-down management, but when people start making, things happen. For example, someone hacked a ukulele, then another person made a guitar, and more were inspired to join in. The result is an “orchestra” that jams in part of the Hackspace during social occasions.

There are hundreds of similar hacker clubs, fab labs and other DIY groups across the United States, the United Kingdom and Europe. The so-called “maker movement” could even be the motor for the next industrial revolution, according to Chris Anderson, a former editor-in-chief of Wired who is now an entrepreneur in the maker sector. In his book Makers: The New Industrial Revolution, Anderson wrote that the availability of increasingly cheap technologies like 3D printers, laser cutters, CNC machines and 3D scanners will do for the physical world what desktop computers did for the internet.

Anderson’s logic is easy to follow: to get into manufacturing, all you need is a business idea, a computer, a 3D printer and a credit card. With machines getting better and cheaper, consumers are increasingly adopting the technology for less than $5,000. Sites such as Ponoko help you design your own 3D objects. You can either print them at home or through portals such as 3D Hubs, which act as print shops and distribution points for local markets worldwide. From jewelry and lampshades to cell phone holders and toys, if you can design it, you can print it and sell it globally.

Some dream that this sort of grassroots making could even reverse a half-century of decline in manufacturing jobs in the United States and Europe. In 2013, President Barack Obama set up the National Network for Manufacturing Innovation to explore these and other emerging developments. In his budget for fiscal year 2014, the president proposed creating a network of up to 15 regional Institutes for Manufacturing Innovation backed by $1 billion in funding. The first of these is the National Additive Manufacturing Institute, a Youngstown, Ohio-based 3D printing organization comprised of academic, corporate and nonprofit groups, also called America Makes. The pilot has attracted 100 members and already co-funded several collaborative projects, government officials report.

Meet the Machines

Across town from Hackspace, on the leafy campus of the University of Nottingham, research fellow Martin Baumers has set up a Maker Bot Replicator 2 on a meeting room table at the university’s EPSRC Centre for Innovative Manufacturing in Additive Manufacturing. The Replicator’s name is a nod to a science fiction gizmo from Star Trek: The Next Generation that could print anything on demand. The Maker Bot looks like a large microwave oven without a door.

As we talk, it prints a scale model of the Empire State Building. The process is mesmerizing. The printer takes a 3D model designed on CAD software and interprets it as a series of wafer-thin shapes stacked on top of each other. The nozzle head buzzes into action, melting plastic (polylactic acid) that it squirts like cake icing onto the build plate until the first slice is complete. The supports that hold the print head in place then notch up a fraction and the printing starts again, adding a new layer on top of the slice that is now cooling. This layering of fine slices of material inspired the term additive manufacturing (AM).

As the model takes shape, a phrase from science writer Arthur C. Clarke comes to mind: “Any sufficiently advanced technology is indistinguishable from magic.” While it looks magical, Baumers is skeptical about talk of an industrial revolution at this stage because there are too many technical limitations in consumer-end machines to safely print objects that are ready to use.

“Accidents could easily happen if there are mistakes during the build process, or the wrong materials are used,” he said. “The objects might just fall apart. They may be unpredictable and, mechanically, they are not good either.”

More importantly, perhaps, he believes the skills needed for industrial-level design are beyond the range of most amateur makers. “The critical mistake of the people who advocate high-tech subsistence production—including the makers—is that the design of 3D products, whatever way you look at it, is a non-trivial task,” he said. “To get yourself over the threshold of being able to design something that actually matches what you need, rather than what you are capable of designing, takes professional training normally, and years of that at a university level.”

In the next room, white-coated lab technicians tend to industrial-scale printers that are making prototype mechanical and medical parts out of much more robust materials, such as nylon and titanium. The techniques are different. Laser sintering printers spread a fine layer of nylon-based powder on the print platform and a laser traces patterns into it, melting the substance into complex shapes, layer upon layer. The process is precision-engineered, so designs can include moving parts or even electrical components, generating the final model in a single printing.

Baumers moves over to another machine, which is printing a model of the university's castle-motif brand from titanium. The request has come from marketing people high up in the university and it is easy to see why: the detail is incredible, from the textured "stone" exterior to a spiral staircase that is visible through a window opening in the side of the tower.

Measuring the Market

The market for both consumer and industrial 3D printers and their associated products is at an all-time high of $3 billion a year, according to Wohlers Report 2014, by industry consultants and analysts at Wohlers Associates. The study shows a compound annual growth rate of 35%—the highest in 17 years. The fastest-growing sector is metal AM, which expanded by almost 76% in 2013. In 2015, GE Aviation will begin to use metal AM to manufacture fuel nozzles for its new LEAP engine, eventually increasing output to more than 30,000 units annually, the report said. Further, orthopedic companies have printed about 90,000 acetabular (hip) cups in titanium, 40,000 of which are already implanted in patients.

Metal AM will grow even faster as companies find ways to use it in more products. Machines and materials are also becoming cheaper and faster, lowering the point at which it is economically attractive to switch to metal AM. "The next couple of years will probably see some amazing announcements with respect to what the aviation industry is going to do with metal and manufacturing," said Tim Caffrey, senior consultant at Wohlers and the report's co-author.

He is less bullish about the maker end of the market, however. "Comparing additive manufacturing and consumer 3D printing is like comparing a Formula One car and a bicycle," he said. While there is a market for a general household printer, he believes it will be relatively small—particularly because the machines can only print something that fits into an eight-inch cube. That is not to say there will not be a demand for the jewelry, sculpture, housewares and other products already offered on sites such as Shapeways, or for speciality items like automotive parts for vintage cars printed in metal.

Industrial AM has fewer limitations, and larger manufacturers are excited about the idea that, with this technology, "complexity is free." With additive manufacturing, engineers can create very complex structures that would not be possible using traditional methods, according to Mark Cotteleer, research director at Deloitte Services. Historically, machines have needed straight-line access to materials. "It's hard to drill a hole around a corner, so curves, channels or intricate lattice structures become very difficult to build without making them in two dimensions and then assembling them," he explained. Because a 3D printer makes objects slice by slice, it is effectively assembling thousands of two-dimensional pieces into a single object in a process that requires no tooling.

But Cotteleer does not believe these innovations are cost-free, particularly in supply chains. Many small, specialist manufacturers provide precision parts to large businesses like automotive manufacturers. As complexity is absorbed into the initial stage of production, those satellite companies become redundant. AM still faces the challenges of sourcing suitable materials and securing safety accreditation for end-use products, so he does not believe it is time to panic just yet. But he does urge suppliers to consider how they are positioned in the supply chain and what function their components play in the overall assembly.

"There will be winners among companies and individuals, just as there has been with the IT revolution," he said. "There will still be demand for people to service, maintain, design and finish. We are not anywhere close to a Star Trek replicator yet."

Managing Manufacturing

Businesses and hobbyists can increasingly scan and print real-life objects, a physical version of the download and duplicate phenomenon that has wreaked havoc on the music and publishing industries. Tracking down and pursuing millions of people for copyright and trademark infringement is next to impossible, after all. But William Simons, counsel at intellectual property law firm Cantor Colburn, doubts it will get too dire for manufacturers. While there will be a threat to copyrights and trademarks, he said, businesses with the right strategy should be able to cope with the challenge.

“If you, as the traditional manufacturer, can supply the demand for your products and secondary goods, there are going to be no knock-offs if you are first in the market,” he explained. Producing well-finished merchandise takes real time and effort, unlike downloading and copying music files. Businesses should be able to take advantage of the global proliferation of additive print shops to create networks of sister organizations that can locally print high-quality products to meet demand. That would require businesses to engage in cross-licensing arrangements to split profits, which he believes may also lead to increased demand for legal expertise in those areas.

In some ways, manufacturing could be going back to the Medieval and Renaissance practice of guilds comprising groups of master craftspeople, he said. A product could be designed by one type of master craftsman and sent electronically to another for local construction and distribution. Companies with large, centralized manufacturing operations that deal in big quantities or replaceable parts are likely to take a hit as a result. In the case of a replaceable part like a lawnmower blade, for example, even a small DIY print shop could compete on price and quality.

Where there are trademark and copyright infringements, however, enforcement could be quite challenging. Currently, large volumes of counterfeit goods come in through national borders, which makes policing easier. Foreign counterfeiters could face stiff competition from those in the United States using 3D printers, who would be harder to catch and would not have to deal with expensive shipping costs.

The Meaning of Making

While there is little doubt that laser cutters and additive manufacturing techniques are transforming business products and processes, Dale Dougherty believes that their rapid rise in popularity taps into something more fundamental. Dougherty founded Make Magazine in 2005 and launched the first Maker Faire in San Mateo, California, a year later. While it has inspired similar events worldwide, Maker Faire gets bigger every year and, in 2013, attracted over 1,000 makers and more than 120,000 attendees.

“We live in a very consumer-oriented culture in which you can buy almost anything, and you need an alternative way to think about that,” Dougherty said. “What do these things that I buy mean and how am I connected to them?

He believes the answer can be found by making something. In doing so, people get a more personal relationship to the objects they own and, in turn, to the world around them. “It’s about the process, not just the object, and turning that from an individual pursuit to something that is collaborative and social,” Dougherty said. He likens making to cooking or gardening: people enjoy the sense of control and the personal involvement.

“A renaissance in creative flowering is just as important as an industrial view,” he said. “It isn’t just business, [3D printing] is giving people the power to do new things. They will use it for art, science, their home and family life.”

But he does not write off the idea that new industrial strategies will come from the grassroots movement. The group of people interested in making is much broader than Dougherty imagined when he first became involved in what he calls “hacking reality.” And, if you want a model for the future of 3D printing, the recent history of technology could serve as a possible blueprint. “When there were only computer mainframes, nobody thought that people would want a home computer and that they would become mainstream,” he said. “But just look what happened.”